# Chapter 2

# Radiation and Tritium Use at the NTLF

Tritium (referred to as T in this document) is the radioactive **isotope** of hydrogen. It is used at the NTLF for beneficial medical research. This chapter explains in general what radiation is and what its biological effects are, what tritium is, and how it is used at the NTLF.

## 2.1 What Is Radiation?

Radiation is defined as the emission and propagation of energy.[1] Also, the energy emitted is called radiation. There are three major types of radiation: electromagnetic, acoustic, and particle. The types of radiation associated with radioactive elements are particle radiation and electromagnetic radiation.

Particle radiation consists of particles that have been ejected from atoms. An **alpha particle** is a heavy particle composed of **neutrons** and **protons**. It can be stopped by a sheet of paper and is not likely to penetrate the outer layer of our skin. A **beta particle** is a high-speed electron. Beta particles are more penetrating than alpha particles. Depending on the energy of the beta particle, it can go through up to two centimeters of living tissue. Beta particles from tritium are not very energetic and cannot penetrate clothing or skin; however, once tritium is inside the body even this minimal penetration energy could be enough to damage tissue.

Electromagnetic radiation includes visible light as well as unseen radiation such as radio waves, x rays, and **gamma radiation**. Certain radioactive elements give off gamma radiation. Gamma radiation travels at the speed of light and is extremely penetrating.

[1]Material in this section is based on the book *Radiation Doses, Effects, Risks* (UNEP, 1985).

Because of their ability to cause changes in the ionization (i.e., chemical bonding characteristics) of atoms and molecules, alpha, beta, and gamma radiation are called **ionizing radiation**. Ionizing radiation (see Figure 1-2) can also cause chemical changes in cells through **excitation**, **dissociation**, and atom **displacements**. These chemical changes can lead to cancer, genetic defects, and developmental and reproductive effects.

An element is radioactive if its individual atoms are undergoing decay, throwing out energy and matter from their nuclei in the form of ionizing radiation, and, in the process, changing into a different element or a different **isotope** of the same element. This decay process goes on continuously, but at different (though specific) rates for different radioactive elements and isotopes. The decay rate of a radioactive element or isotope is expressed in terms of its **half-life**. A half life is the amount of time it takes for half the atoms in a quantity of an element or isotope to decay. The number of individual atomic decays that take place each second is called the **activity**, and is measured in **becquerels** or **curies**. A curie (Ci) is equal to 37,000,000,000 (37 billion) becquerels (Bq).

## 2.2 Tritium

Tritium has a radioactive half life of 12.3 years. When tritium undergoes radioactive decay, it is transformed into nonradioactive helium through emission of a beta particle from its nucleus. Tritium's beta particles have a very low penetrating ability—not enough to penetrate skin. Thus, as long as it is outside the body, tritium represents little or no hazard.

However, because tritium has physical properties that are similar to hydrogen's, it acts much like hydrogen in the environment and the human body. Like hydrogen, it can be ingested, inhaled, or absorbed through the skin .

Tritium is found in the environment in three principal forms—molecular tritium ($T_2$ or HT), tritiated water (HTO, as opposed to $H_2O$), and organically bound tritium (OBT) in which it is chemically bonded to organic molecules. Tritiated water is the most abundant chemical form of tritium in the environment.

The properties of HTO are very similar to water. Because the difference in atomic weight between HTO and $H_2O$ is small, they are actually more similar than tritium and hydrogen. HTO is much more readily taken up by organisms and environmental media than molecular tritium.

OBT forms when organic molecules are exposed to tritium gas or HTO. This could happen in the human body or through uptake of HTO by plants. OBT has a different metabolism than HTO and can be retained in the body for somewhat longer periods.

### 2.2.1 Sources of Environmental Tritium

Tritium is continuously released to the environment from both natural and man-made sources. Cosmic ray reactions with molecules in the upper atmosphere are the primary natural source of tritium. The earth's crust also contributes a minor amount of tritium to the global inventory, but in recent decades human contributions have far exceeded those of natural sources. In particular, atmospheric tests of nuclear weapons in the 1950s and 1960s produced a large portion of the tritium now in the environment. (Fortunately, this inventory will continue to decrease by 50% every 12.3 years as long as no more nuclear weapons are tested.) Tritium from underground testing is considered an unlikely source of atmospheric tritium.

Other smaller human contributions to environmental tritium include normal and accidental releases of tritium from nuclear reactors, and consumer products such as marine compasses (containing an activity of about 0.5 Ci), luminous dials on watches, and self-illuminated exit signs (containing an activity of about 20 Ci) in buildings.

The combined global inventory of natural and human tritium emissions is about 50 times greater than tritium levels from natural sources alone. The resulting estimated average concentration of tritiated water in the earth's waters is 0.00000027 $Ci/m^3$ (or 10 Bq/L).

### 2.2.2 Health Effects of Tritium

According to Straume [1993] few studies are available on tritium-induced health injury in humans. Health-risk estimates for tritium are therefore based on the large number of experiments with animals and cell cultures. These experiments show that exposure to tritiated water results in mutations and cell disruptions that can lead to the health effects possible for ionizing radiation—cancer, **heritable genetic effects**, and **reproductive and developmental effects**.

These health risks are associated with exposures to tritium through **inhalation**, **ingestion** of HTO or OBT, or absorption of HTO through the skin. The health effects of ionizing radiation are proportional to the energy carried by the radiation and delivered to living cells.

### 2.2.3 How People Come in Contact with Tritium

Because the energy of electrons emitted during the decay of the tritium nucleus is insufficient to penetrate skin, this report does not address external radiation exposure, but only internal dose routes. The following exposure pathways were considered:

- Tritiated water vapor entering the body through respiration
- Tritium ingested with water during swimming or wading, home-grown foods, or breast-milk (in the case of infants) and absorbed into the body through the gastro-intestinal tract
- Tritium from tritiated water vapor in air taken through the skin
- Tritium from tritiated water in surface water taken through the skin during activities that involve dermal contact with the contaminated water, i.e., washing, swimming, and wading in surface water
- Tritium transferred from the body water of pregnant women to the developing fetus

### 2.2.4 Potential Risks

When tritiated water enters the body it acts just like normal water, spreading throughout the body and delivering a uniform radiation **dose** to all soft tissues. Using the modeling techniques discussed in Chapter 4, we determined that it takes about 10 days for half the intake or uptake of tritiated water to be discharged out of the body. This period is called the *biological half life.* For tritium that is ingested as OBT (e.g., from garden vegetables grown by residents of Zone 2), the biological half-life is on the order of 48 days.

## 2.3 Tritium Use at the NTLF

The NTLF is the only facility at LBNL that uses tritium in significant quantities, and accounts for almost all airborne tritium releases from LBNL. The NTLF occupies Building 75 on the LBNL site (see Figure 1-1).

### 2.3.1 Tritium Labeling

Biomedical researchers use tritium labeling to investigate administration, distribution, metabolism, and excretion characteristics of new pharmaceuticals, among many other applications. These investigations are carried out on cell systems, not animal or human subjects. More than 250 users have visited the NTLF since 1982 to label almost 500 compounds.

Tritium labeling is unique, as well as cost effective and precise, in its ability to reveal individual steps in chemical reactions as well as their yields. The tritium labeling process replaces hydrogen atoms with tritium atoms in the molecule to be studied. The labeled molecules are radioactive and therefore readily identified and traced.

The NTLF provides important public health benefits. In addition to its tritium labeling operations, the NTLF is a research facility. Collaborative research projects initiated over the past three years have shown new ways to use tritium labeling to study cell metabolism and biomolecular structure and function. NTLF staff members are active in publishing articles and reports on these and other subjects and in presenting their work at scientific conferences.

## 2.3.2 Tritium Releases at the NTLF

Like hydrogen, the tritium molecule's small size allows it to diffuse easily through all kinds of materials. This makes it difficult for a system to be fully resistant to tritium leakage. NTLF design and operations provide multiple layers of defense to restrict the release of tritium to the environment. From 1970 to 1995 tritium releases from the NTLF averaged 138 Ci/yr. In 1990 an emissions reduction plan was implemented that has substantially reduced annual emissions (see Figure 2-1 and Appendix I).

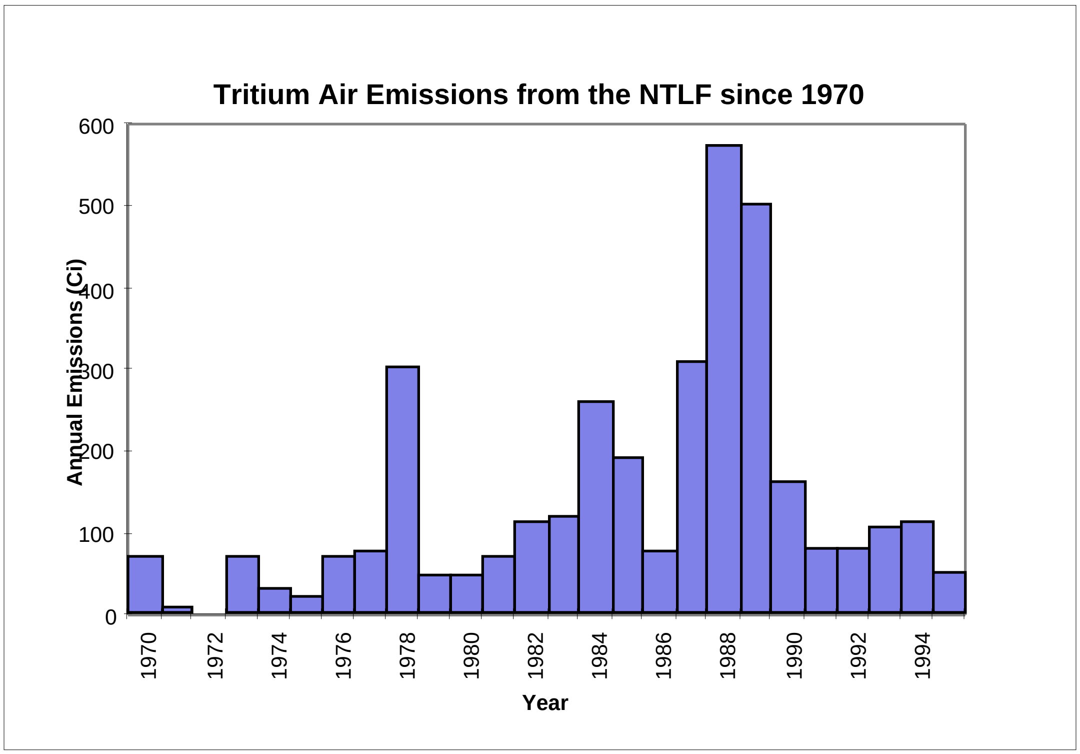


**Figure 2-1.** Annual releases of HTO from the NTLF.